

Effect of moisture and fungal exposure on the mechanical properties of hem-fir plywood

WANG Wei-hong¹, Scott Kent², Camille Freitag², Rorbert J. leichti², Jeffrey J. Morrell²

¹ Key Lab. of Bio-based Material Science and Technology of Ministry of Education, Northeast Forestry University, Harbin 150040, P. R. China

² Department of Wood Science and Engineering, Oregon State University, USA

Abstract: Hem-fir plywood were exposed to two brown rot fungi, *Gloeophyllum trabeum* and *Postia placenta*, and one white rot fungus, *Trametes versicolor*, to investigate the effect of fungal decay on mechanical properties of plywood. Results showed that modulus of rupture (MOR) and modulus of elasticity (MOE) of hem-fir plywood declined significantly by inoculating fungi, and weight loss of sample had a modest decrease. The fungi also made a greater effect on MOR than on MOE. Of three fungi, *Postia placenta* caused a most significant weight loss, and *Gloeophyllum trabeum* resulted in a largest flexural properties loss. Substantial declines in MOR and MOE of hem-fir plywood were also observed when the plywood samples were stored under wet conditions over 15 weeks, even in the absence of fungal attack.

Keywords: Fungus decay; Weight loss; Flexural properties; Moist condition; Plywood; MOR, MOE

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Introduction

Plywood has been a kind of dominant materials for sheathing in houses and buildings in the past several decades. Generally the composite durability is related to the decay progress that is normally evaluated based on the weight loss or visual assessment. Many literatures have shown that the early stages of fungal decay were often characterized by dramatic decreases in some mechanical properties, but with only modest losses in wood components and minimal changes in appearance (Wilcox 1978; Scheffer 1936; Green *et al.* 1991; Winandy and Morrell 1993; Imamura 1993; Kim and Ra 1996; Petersen and Schwandt 1991; Schmidt *et al.* 1978). Therefore, the method of normal decay evaluation may not truly reflect the changes of some mechanical properties caused by fungal attack.

The objective of this research is to determine the effect of rot decay and white decay on bending properties of plywood, so as to develop an effective method for evaluating the decay and the residual service-life of wood and composite materials under adverse conditions.

Material and methods

Samples (330 mm × 76 mm) came from the commercially produced hem-fir plywood (5 ply, 12 mm in thickness), which were oven-dried (104°C) and weighed. In order to get high enough moisture content, samples were immersed into water in a pressure vessel, subjected to a vacuum with 30 min, and then raised to a pressure of 550 KPa with 90 min. The moisture content of treated samples reached a range of 80% to 90%.

Sets of plywood strips were sealed and laid flat in autoclavable bags and autoclaved for 30 min at 120°C. Then the bags were heat-sealed and refrigerated to ambient. Each bag was cut a

20 mm slit and injected sterile air and 200 µL suspension of hyphal spore on sample surface. Then, the slits were resealed with tape and the bags were incubated at 30°C. And similarly bagged specimens without fungal inoculum were established to serve as controls. The fungi employed in test were brown rot fungi, *Gloeophyllum trabeum* (Pers ex Fr.) Murr. (Isolate Madison 617) and *Postia placenta* (Fris) M. Larsen et Lombard (Isolate Madison 698), and white rot fungus, *Trametes versicolor* (L. ex Fr.) Pilat (Isolate Madison R105).

Samples were exposed to fungi for 5–15 weeks after inoculation. Six samples exposed to each fungus were removed after every 5 weeks, then oven-dried and weighed to determine wood weight loss. The samples reached a stable weight at 20°C and 60% of relative humidity. Modulus of rupture (MOR) and modulus of elasticity (MOE) of these samples were detected according to the procedures described in D 1037 (ASTM2002). A 50-mm section was removed from the end of the each test specimen to determine the moisture content.

Results and discussion

Weight loss is a traditional measure to evaluate the ability of fungi to utilize cellulose, hemicellulose, and lignin structural polymer of the wood cell for nutrition. The test results showed that three fungi attacked inoculated samples rapidly and caused increasing weight loss and strength reduction over the exposure of 15 weeks (Table 1). Although all of the inoculated samples were colonized by fungi, they were more susceptible to *Postia placenta* decay, which resulted in most weight loss during the period of treatment. *Gloeophyllum trabeum* and *Trametes versicolor* grew slowly, and there is not significant difference in weight loss between the two fungi during the first 15 weeks. The difference of weight losses reflected the relative ability of fungus to degrading materials.

The effects of fungi decay on mechanical properties are shown in Fig. 1 Even though at the same level of weight loss, sample properties also showed different change. These differences exist not only between brown decay fungus and white decay fungus, but also between brown fungi, such as between *Gloeophyllum trabeum* and *Postia placenta*. Therefore, weight loss is a rela-

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Biography: WANG Wei-hong (1968-), female, Ph.D., associate professor of Northeast Forestry University, Harbin 150040, P.R. China.

Email: weihongwang2001@yahoo.com.cn

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tively insensitive measure and can not reflect the real damage induced by fungi decay to the mechanical properties of materials.

Table 1. Effect of moist and fungal exposure on the MOR and MOE of hem-fir plywood

Exposure period, (week)	Average MOR (MPa)			Average MOE (GPa)			Average mass loss (g)		
	<i>Gloeophyllum trabeum</i>	<i>Postia placenta</i>	<i>Trametes versicolor</i>	<i>Gloeophyllum trabeum</i>	<i>Postia placenta</i>	<i>Trametes versicolor</i>	<i>Gloeophyllum trabeum</i>	<i>Postia placenta</i>	<i>Trametes versicolor</i>
0	44.35 (11.59)	44.35 (11.59)	44.35 (11.59)	6.25 (1.57)	6.25 (1.57)	6.25 (1.57)			
5	46.34 (8.91)	43.31 (8.60)	35.56 (3.75)	6.51 (0.92)	6.51 (0.92)	5.36 (0.50)	2.20 (0.53)	2.53 (0.69)	2.20 (0.34)
10	29.55 (6.25)	27.33 (4.99)	27.17 (4.53)	4.60 (0.46)	4.43 (0.57)	4.15 (0.57)	3.76 (0.84)	5.65 (1.12)	5.21 (0.76)
15	15.23 (2.45)	25.10 (2.31)	22.74 (3.61)	2.52 (0.28)	3.88 (0.32)	3.36 (0.51)	5.36 (0.85)	6.28 (2.38)	5.84 (1.79)

Note: Values in parentheses are standard deviations

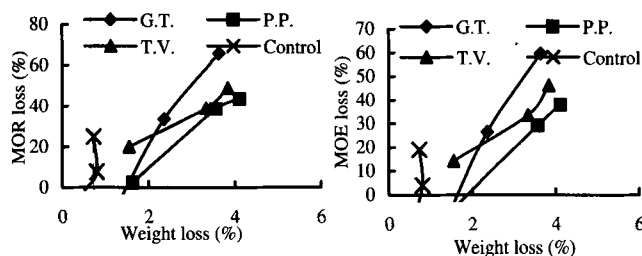


Fig. 1 Relationship between mass loss and MOR and MOE

Note: G.T.—*G. trabeum*, P.P.—*P. placenta* and T.V.—*T. versicolor*

The relative magnitudes of changes in flexural properties caused by *G. trabeum* and *T. versicolor* were not consistent over 15-week exposure. When weight loss was less than 2 percent, the flexural properties of sample treated by *T. versicolor* showed the highest loss among the treatments. When weight loss was more than 2 percent, the MOR of sample treated by *G. trabeum* had the highest percentage of loss. At the end of exposure, MOR of the samples treated by *G. trabeum* lost 65.65%, which was corresponded to a weight loss of 3.64%. In the entire test period, the samples treated by *P. placenta* had the least quality deterioration with a MOR loss of 43.31% and weight loss of 4.11% at the end of test. Similar results were achieved in MOE. All three fungi had more significant effect on the change of MOR (5%–10%) than that of MOE.

Based on the test results, it is believed that brown fungi induced substantial changes in material properties at relatively early stages of attack, which was similar with results obtained by Wilcox (1978). Usually, white rot fungi tended to preferably decay hardwoods, but in this test, *T. versicolor* showed more significant effect on MOR and MOE than *P. placenta*. *T. versicolor*, and also caused significant decay to hem-fir material.

Typically, degradation of mechanical properties is often attributed to fungi colonization in fungi decay test. However, it is worth noting that MOR and MOE in our test samples exposed under wet condition in the absence of the fungus declined from 44.35 MPa to 33.34 MPa, and from 6.25 GPa to 5.06 GPa, respectively, over the 15 week period. Similar effects occurred in OSB and another kind of plywood test. Moisture content is one of the most important factors required by fungi growth. It has been found that the moisture content of 30% or more is necessary for fungal growth (Highley 1999). Since the control samples had high moisture content, test results implied that moisture could be another key factor in weakening material properties.

As a rule, bonding strength should be greater than the strength of wood component in composite in order to utilize wood fullest. In our test, control samples obtained 75% moisture content. The

progressive effects with time implied a fundamental that moisture can make an effect on the wood/resin interface. Declines in properties were thought to be the result of separation between wood and resins. Degradation resulted in not only from fungi decay but also from the adverse effect of moisture.

Conclusion

Both brown and white rot fungi degrade MOR and MOE of hem-fir plywood with modest weight loss, and MOR loss is more than MOE loss. Strength losses of hem-fir plywood caused by different fungus are different even at a same weight loss level. *G. trabeum* showed the highest decomposing ability for hem-fir plywood among the three testing fungi. Even though white rot fungi usually tend to decay hardwoods, and *T. versicolor* attacks hem-fir material at a slight weight loss, it had greater damage to the properties compared with *P. placenta*.

It is difficult to differentiate the effects of the fungus on hem-fir plywood from that of the water. Decrease of the bending strength in control samples reflects the fact that moisture has a serious opposite effect on the properties of hem-fir plywood, and repeated wet-dry would accelerate this effect. While fungal damage is often viewed as a serious concern, our test results highlighted the importance of removing moisture sources not only for avoiding fungal attack but also for reducing effects of moisture induced on material properties.

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